Forecasting Lab (FLAB)

1a. Given centrally produced weather charts, forecast upper-air and surface weather elements features with at least 75% accuracy within 14 hours based on an evaluation checklist.

Hemispheric Characteristics

- Long-waves
  - Barotropic. Short-waves cause baroclinicity (distortion) within long-wave pattern.
  - Best seen at 200 and 300 mb levels. Baroclinicity decreases above mid-levels.
  - Wavelength: 60-120˚ of longitude.

Hemispheric Characteristics

- Zonal index: Strength of west to east component of mid-latitude westerly flow.
  - High zonal: Basic flow west to east.
    - Little north to south energy (heat and moisture) transfer.
    - Small west to east temperature variations.
    - Systems tend to be weak and move rapidly.
  - Low zonal: Basic flow north to south.
    - Large scale north to south energy transfer occurs.
    - Large west to east temperature variations.
    - Systems are often strong with large cloud/precipitation shields.

Hemispheric Characteristics

- Locating long-waves
  - The 0-5 wave chart (most short-wave distortion is removed from this chart).
  - The 200 and 300 mb charts are most commonly used.
  - Satellite method
    - Main axis of Polar Front Jet (PFJ) outlines current long-wave pattern.
    - Same techniques used for PFJ identification help define the long-wave pattern.

Hemispheric Characteristics

- Significance of long-waves
  - Define average storm track.
  - Cyclones tend to intensify near and just downstream from long-wave trough axis.

Hemispheric Characteristics

- Progging the long-wave pattern
  - Thermal advection
    - Major short waves move through the long-wave pattern and provide CAA/WAA that affects the pattern (Review Baroclinic Instability theory).
    - CAA deepens long-wave troughs, weakens long-wave ridges.
    - WAA builds long-wave ridges, fills long-wave troughs.
    - Evaluate advection on long-wave scale using 1000/500 mb thickness chart.

Hemispheric Characteristics

- What occurs upstream of long-wave ridges/troughs affects downstream troughs/ridges.
  - Intensification of an upstream ridge may increase CAA into downstream trough.
  - Intensification of an upstream trough may increase WAA into downstream ridge.

Hemispheric Characteristics

- Subgradient/Supergradient upper-level winds

  - Subgradient (confluent) flow causes winds to cross contours toward lower heights, increasing mass to left of flow (fills troughs/weakens ridges when between axis of long-wave feature and downstream inflection point).

Hemispheric Characteristics

- Supergradient (difluent) flow causes winds to cross contours toward higher heights, increasing mass to right of flow (deepens troughs/builds ridges when between axis of long-wave feature and upstream inflection point).

- Evaluate sub/supergradient conditions using 300 mb chart.

Hemispheric Characteristics

- Long-wave movement
  - Generally progress slowly
    - The stronger the westerly component of the flow, the faster the wave; weaker westerly component, the slower the wave.
    - The larger the wavelength the slower the wave; the smaller the wavelength the faster the wave.

Hemispheric Characteristics

- Can remain stationary or retrogress
  - Retrogression - often a discontinuous process.
  - While new long-wave trough/ridge forms to west, old trough/ridge moves east and fills/weakens.
  - Frequently occurs with blocking ridges.

Hemispheric Characteristics

– Effects of Temperature Advection

- Long waves will orient or move in the direction of strongest temperature advection.

- CAA will cause the long-wave trough to either progress, remain quasi-stationary or retrogress, depending on the location of the CAA relative to the system axis.

Hemispheric Characteristics

- WAA will cause the long-wave ridge to either progress, remain quasi-stationary or retrogress, depending on the location of the WAA relative to the system axis.

Hemispheric Characteristics

– Effects of Jet Maxima

- Long-wave troughs/ridges deepen/build and remain quasi-stationary as a Jet Max moves into base/crest of feature (supergradient condition).

- Jet Max near axis of trough/ridge expect feature to progress with little or no amplitude change.

Hemispheric Characteristics

- Troughs/ridges fill/weaken and progress more rapidly as maxima move downstream of long-wave axis (subgradient condition).

- Three long-wave patterns and jet max effect on each
  - Northwest jet max approaches sharply curved ridge, trough axis oriented NE-SW.
    - » Trough fills (centrifugal force throws mass into trough).
    - » Reorients more N-S
    - » If closed low present in trough base it opens and ejects rapidly NE.

Hemispheric Characteristics

- Westerly Jet Max approaches flat ridge, blocking ridge east of downstream trough (trough oriented N-S)
  - » Trough fills (Centrifugal force throws mass into trough).
  - » No reorientation of trough axis.
  - » If closed low present in trough base, it opens and moves northward (Blocking ridge allows no eastward progression).

Hemispheric Characteristics

- Southwesterly jet max approaches sharply curved ridge, deep trough positioned just downstream.
  - » Trough fills (centrifugal force causes addition of mass into top of ridge).
  - » Cut-off low may form (as ridge builds, jet axis overshoots or “bridges” trough).

Hemispheric Characteristics

- Blocking patterns
  - Definitions
    - Blocking - large scale obstruction to normal west to east progression of migratory baroclinic systems.
    - Blocking High/Ridge - warm barotropic high or long-wave ridge responsible (alone or in part) for blocking.

Hemispheric Characteristics

- Blocking Low/Trough - cold barotropic low or long-wave trough responsible (alone or in part) for blocking.

Hemispheric Characteristics

– Characteristics

- Occurs at upper levels. Surface reflections are often observed, but blocking caused by upper levels.
- Associated with extremely low zonal flow patterns.
- Normally caused by group of systems. i.e. blocking high in conjunction with a blocking low (Rex block).

Hemispheric Characteristics

- Basic zonal flow splits into two segments for a significant distance, one branch on poleward trajectory the other on equatorward trajectory.

- Persistent. Lasts approximately a week or more.

- Two most common blocking patterns: Rex block (High north of a low) and Omega block.

Hemispheric Characteristics

- Decaying waves (cold barotropic) appear similar to cut-off lows on satellite imagery, but differences exist.
  - Located north of Polar Front Jet.
  - Have remnants of frontal cloud band wrapped around low.
  - Cloud band dissipates over time and low center will be identifiable as circulation in pattern.
  - Normally a well defined band of deformation zone cloudiness exists north of low center.

Hemispheric Characteristics

- Subtropical highs are identifiable on satellite imagery by considering flow pattern in region.
  - Polar Front Jet is poleward of subtropical highs. Systems north of subtropical highs generally move west to east.
  - Tropical systems equatorward of subtropical highs generally move east to west.

Hemispheric Characteristics

- Cut-off highs
  - Warm barotropic
  - Vertically stacked
  - Slow moving or stationary
  - Polar Front Jet often splits with two branches flowing around high.

Hemispheric Characteristics

- High amplitude trough normally exists upstream.

- A well defined band of baroclinic zone cirrus will form with this trough/ridge couplet.

- Large area of clear skies exists at center.

Synoptic features

- Development of major short waves
  - Thermal advection
    - When pattern is high zonal, north-south temperature gradient builds.
      - Represents increase in available potential energy for short-wave development.

Synoptic features

- Potential becomes kinetic energy as short-waves amplify through process of baroclinic instability.
  - » Resultant major short-wave troughs are associated with thermal (cold) advection, divergence aloft, stack to surface as baroclinic lows.
  - » Resultant major short-wave ridges are associated with thermal (warm) advection, convergence aloft, stack to surface as baroclinic highs.

Synoptic features

- Progging intensity changes in major short waves
  - Effects of thermal advection with diffluence/confluence
    - Cold air advection (CAA) is primary mechanism causing amplitude increase in short-wave troughs (results in falling upper level heights).
      - Major short-wave troughs intensify under difluent upper level flow (exhaust).
      - Diffluent flow often occurs with negatively tilted troughs.

Synoptic features

- Warm air advection (WAA) is primary mechanism causing amplitude increase in short-wave ridges (results in rising upper level heights).
  - Major short-wave ridges intensify under confluent upper level flow (adds mass to column).
  - Often height rise centers will move northwest as major short-wave ridges build.

Synoptic features

- Deepening short-wave troughs may influence intensity of downstream short-wave ridges (similar to long-waves).

- Building major short-wave ridges may influence intensity of downstream short-wave troughs (similar to long-waves).

Synoptic features

- Major short-wave troughs associated with southward moving vorticity maxima tend to deepen.
  - Evaluate trough location in relation to long-wave pattern.
  - Short-wave trough should be moving into long-wave trough for rule to work.

Synoptic features

- Stronger NVA behind than PVA ahead of a short-wave trough indicates the trough is filling.

- Major short-wave troughs deepen while moving into long-wave troughs, fill while moving into long-wave ridges.

Synoptic features

- Large amplitude waves generally move slower than small amplitude minor short-waves.
  - Large amplitude waves use energy for deepening/building.
  - Minor short-waves use energy for movement.

Synoptic features

- Steering major short-wave features
  - Extrapolation and continuity
    - Establishes history of system (continuity) and projects into future (extrapolation).
    - Works well for periods of 12 to 24 hours, rapidly loses accuracy beyond 24 hours.
    - Assumes changes in pattern will be slow and gradual.

Synoptic features

- Big disadvantage is new developments not considered (past through present trends won’t continue indefinitely).

Synoptic features

- Constant movement
  - Assumes future movement the same as past movement.
  - Simplest method. Only one time period required. (i.e., wave moves 20 knots for 12 hrs forecast 20 knots for next 12 hrs)

Synoptic features

- Constant rate of change
  - Requires at least two time periods of continuity.
  - Forecast speed increase/decrease at a fixed rate. (i.e., wave moves 15 knots first 12 hrs, 20 knots second 12 hrs, forecast 25 knots for next 12 hrs)

Synoptic features

- Constant percentage change
  - Requires at least two time periods of continuity.
  - Similar to constant rate of change but assumes speed change at fixed percentage rather than fixed rate. (i.e., wave moves at

Synoptic features

- Control line extrapolation
  - Used when speed varies for different sections of system.
  - Useful for moving fronts/troughs.

Synoptic features

- Progging intensity changes in upper highs/lows
  - Upper highs
    - Expect little or no intensity change when isotherms concentric to contours.
    - Strengthen when warm air advects into west side, weaken when cold air advects into west side.

Synoptic features

- Blocking highs strengthen when moving westward, weaken when moving eastward (ensure strong WAA is occurring between inflection point and major short-wave ridge axis).

Synoptic features

– Upper lows

- Deepen when cold air is advected into west side, fill if warm air is advected into west side.
- Deepen when adiabatic cooling effects the upper level low. Fill when latent heat effects the upper low.
- If a low height center is moving into a long-wave trough the low will tend to deepen.

Synoptic features

- Divergence/convergence associated with jet maxima can cause intensity changes to upper lows. Evaluate position of divergence/con quads with respect to position of low center.

Synoptic features

- Steering rules for upper highs/lows
  - Upper highs
    - Highs and/or vorticity minima move with the strongest winds around the high (remaining right of jet).

Synoptic features

- Upper highs follow slightly to right of track of associated height rise center.
  - Most height changes relate to short-wave movement.
  - Unusually large geographic areas of height change may indicate change in long-wave pattern.
  - If present, evaluate why changes are occurring and prog necessary long-wave changes.
  - This will affect steering and intensity changes of upper systems.

Synoptic features

- For speed use extrapolation.

Synoptic features

- Upper lows
  - Upper lows and/or vorticity maxima move parallel to direction of max winds around low but remain left of jet.
    - Works best if strongest winds are NORTH or SOUTH of the low.
    - Ensure that a cut-off low is not developing.

Synoptic features

- Cut-off lows will not usually move out of SW US until a strong short-wave approaches Pacific NW. This short-wave acts as a “kicker”.
  - Ensure “kicker” has large enough wavelength and amplitude to force low to open and move out.
  - If low begins to move, it will do so in direction of strongest wind around low.

Synoptic features

- Upper lows follow slightly left of track of associated height fall center.
  - As with upper highs, unusually large areas of height change (falls in this case) could signal change in long-wave pattern.
  - A change in long-wave may affect steering/intensity of major short-waves.
- For speed use extrapolation.

Synoptic features

- Progging isotherms in major short-wave features
  - Maintain similar contour/isotherm relationship from analysis to prog.
    - Amplitudes of thermal troughs/ridges change slowly.
    - Isotherms move at about same rate as short-waves.

Synoptic features

- Isotherms associated with certain features should not be advected.
  - Heat lows/leeside troughs
    - Intense heat lows often reflect to 700 mb as ridges due to their warm core structure.
    - Do not advect these thermal patterns.
    - Will dissipate with air mass change.

Synoptic features

- Plateau highs
  - Reflect as warm barotropic highs aloft.
  - Tend to remain until long-wave pattern changes.

– Cold pockets

- May rotate around low centers at all levels.
- If pocket becomes coincident with low center, tends to remain so.

Synoptic features

- Progging moisture with major short-wave features.
  - Dew-point depressions of 2° C or less are considered significant for progging development of clouds/precipitation.
  - Before progging analyzed moisture areas, compare with observed clouds. If no clouds exist in area, significance and accuracy of observations are questionable.

Synoptic features

- Moisture areas advect with major short waves.

Synoptic features

- Forecast moisture based on source regions.
  - Cold cP airmass won't hold much moisture, isn't likely to produce much precipitation.
  - Warm mT airmass (Gulf of Mexico) possesses abundant moisture, can produce great deal of precipitation.

Synoptic features

– Progging moisture increase/decrease

- Ahead of deepening major short-wave trough (divergence increasing), forecast increase at that level.
- Ahead of filling major short-wave trough (divergence decreasing), forecast decrease at that level.
- Increase/decrease could be due movement over oceans, lakes, land.

Synoptic features

- Orographic effects
  - Ensure onshore flow is occurring.
  - Terrain should be at/just below elevation of your chart.
  - Mild orographic effects may cause stratiform conditions up to 850 mb (approx. 5,000 ft).

– Be familiar with typical synoptic moisture patterns.

Sub-synoptic Features

- Characteristics of minor short waves
  - Have small wavelengths.
  - Do not reflect to surface as baroclinic systems.
  - Minor short-wave troughs/ridges can develop into major short waves as they move into long-wave troughs/ridges.

Sub-synoptic Features

- Minor short-wave troughs can cause isolated areas of precipitation (sufficient moisture must be available in area prior to development).

Sub-synoptic Features

- Using vorticity chart to detect minor short waves
  - Vorticity lobes, comma shaped clouds, thermal troughs, and moisture. All are possible indicators of minor short-wave existence.
  - Use satellite in conjunction with vorticity to evaluate comma shaped cloud patterns.

Sub-synoptic Features

- Vorticity advection lobes are useful for detecting otherwise “masked” minor short-wave troughs moving over long-wave ridge.

Sub-synoptic Features

- Progging minor short-waves
  - Intensity changes
    - Minor short-wave troughs associated with southward moving vorticity maxima tend to deepen (short waves should be moving into long-wave trough).
    - Stronger NVA behind than PVA ahead indicates filling.

Sub-synoptic Features

- Minor short-wave troughs intensify while moving into long-wave trough, fill in long-wave ridge.

Sub-synoptic Features

- Movement
  - Contour/isotherm relationship (wave phase relationship)
    - Evaluate temperature advection into minor short-wave trough from upstream inflection point to system axis.
    - Isotherms/contours 90˚ out-of-phase, short wave moves at 50% of 500 mb wind speed or 70% of 700 mb wind speed.
    - The more out of phase, the faster the movement.

Sub-synoptic Features

- 180˚ out-of-phase, wave moves at 70-100% of 700 mb wind speed.
- Phase relationship remains same with time (as with major short waves).

- Constant movement, rate of change, percentage change, all the same as with major short waves.

Sub-synoptic Features

– Moisture

- May be due to isolated convective activity.
- Ensure activity still occurring before progging persistence.

Progging surface synoptic features

- Progging cyclogenesis of baroclinic lows
  - Favored areas
    - At and just downstream of long-wave trough axis.
    - Negatively tilted troughs with strong difluence aloft.
    - Underneath areas of difluent upper-level flow (winds upstream are greater than those downstream from trough axis).

Progging surface synoptic features

- Under divergent area ahead of approaching jet max.

Progging surface synoptic features

- Where a vorticity max with strong divergence interfaces with an existing weak low-level thermal gradient (Petterssen's rule).
  - A definite vorticity advection lobe will be associated with each unstable wave on a frontal boundary (source of divergence).
  - Expect development along slow moving or stationary fronts when a strong vorticity advection lobe is 5 to 7˚ upstream.
  - If system occludes, vort max will stack closer to surface low.

Progging surface synoptic features

- When several unstable waves exist along front, expect wave associated with strongest upstream divergence to develop at expense of others.

Progging surface synoptic features

- Special case surface lows
  - Lee-side troughing
    - Associated with subsidence and drying.
    - Not directly visible on satellite imagery.

Progging surface synoptic features

- A low amplitude ridge is often present over mountains.
  - Ridging is consistent with warming due to compression.
  - The low amplitude allows upper level winds to have a strong westerly component (high zonal).
  - Strong westerly flow is sometimes evident on satellite due presence of features such as rotor clouds.
- An upper-level trough is sometimes located to the west (near west coast in case of Rockies).

– **IR:**

Progging surface synoptic features

- East coast lows
  - Cyclogenesis common along east coast during cold season.
  - Long-wave pattern normally features a ridge over central or western U.S. and a trough just inland from east coast.
  - A frontal system located offshore, just downstream from trough axis. System extends into Gulf of Mexico.

Progging surface synoptic features

- Stable waves develop in Gulf and propagate northeastward along front.
- A weak short-wave trough moves southeastward down long-wave ridge intensifying as it approaches long-wave trough axis.
- As this short-wave approaches surface front, intense cyclogenesis occurs, often times near Cape Hatteras, NC (Hatteras Low).

Progging surface synoptic features

- Alberta lows
  - Form in lee-of-Canadian Rockies and move southeast. Common during cold season.
  - Long-wave pattern features ridge over western U.S. and trough along east coast.
  - A rapidly moving short-wave trough causes cyclogenesis along lee of mountains.
  - Strong northwesterly flow moves low rapidly east/southeastward.

Progging surface synoptic features

- Surface low is typically weak and precipitation light since initially moisture is limited.
- System often intensifies rapidly as it reaches base of long-wave trough.
- Cloud/precipitation shield will grow as system taps gulf moisture.
- Many east coast lows originate this way.

Progging surface synoptic features

- Explosive cyclogenesis

  - An explosively deepening baroclinic low which deepens in excess of 24 mb in a 24 hr period. Known as a “bomb”.

    - Important because of extremely hazardous weather produced (high winds, heavy precipitation, if over water high seas, etc.).

    - Poorly forecast by present numerical models.

Progging surface synoptic features

- Climatology
  - Favored locations
    - » Most common over the ocean, just north of strongest sea surface temperature gradient associated with warm Gulf Stream and Kuriosho currents.
    - » Most common in Pacific, more intense in Atlantic.
    - » Rare over land but have on occasion been observed in Eastern U.S.

Progging surface synoptic features

- Seasonally
  - Winter time phenomena.
  - Common in Atlantic in February, Pacific in December.

Progging surface synoptic features

- Synoptic climatology
  - » Form at or just downstream from long-wave trough as short-wave trough approaches region.
  - » Form just north of strongest wind band under difluent upper flow.
  - » Closely related to development of low zonal flow and blocking patterns.
  - » Often first indication of major long-wave pattern change.

Progging surface synoptic features

- Observed structure
  - Strong convection occurs at and near center of low.
  - Maximum surface winds, often approaching hurricane force, occur within 60 nm of low center.
  - Most lows which obtain very low central pressures (<970 mb) undergo explosive cyclogenesis.
  - Deep cold barotropic lows (sub-polar lows) often found in the Aleutian/Icelandic regions originate as bombs in the favored regions over Kuriosho/Gulf Stream currents.

Progging surface synoptic features

- Occasionally, two jet maxima exist in a region of cyclogenesis, one embeded in the northern branch of the PFJ, the other in the southern branch of the PFJ. Explosive cyclogenesis will be enhanced when the developing low is positioned in the divergent quadrants of both jets (right rear of the northern max, left front of the southern max).

Progging surface synoptic features

- Dynamics of development
  - Baroclinic instability and self-development are important, but can't alone explain explosive cyclogenesis.
  - Strong tendency to form over water suggests other influences.

Progging surface synoptic features

- While not sensitive to sea surface temperature (SST) bombs normally develop in regions of strong SST contrast.
  - » Cold polar air moves off continent and over warm current, modifying rapidly from below.
  - » Latent and sensible heat are transferred from water to air intensifying baroclinicity in region.
  - » Stability decreases creating a situation where widespread convection occurs near developing low.
  - » Convection leads to more latent heat release, enhancing development.

Progging surface synoptic features

- Progging dissipation
  - Upper-level support (short-wave trough) outruns surface feature.

Progging surface synoptic features

- When a baroclinic low evolves through it's life cycle becoming cold barotropic (decaying wave).
  - Boundary layer convergence in conjunction with diminishing upper-level exhaust adds mass to column filling surface low.
  - Adiabatic cooling of rising air causes thickness of column to decrease so upper low remains.

Progging surface synoptic features

- Progging anticyclogenesis of baroclinic highs
  - Favored areas
    - At and just downstream from long-wave ridge axis.
    - Underneath areas of confluent upper-level flow (winds downstream are greater than those upstream from ridge axis).

Progging surface synoptic features

- Tend to develop behind cold fronts when vorticity minima advection lobes are within 5 to 7˚ upstream.
- On upstream side of strong vorticity maxima where strong convergence exists.

Progging surface synoptic features

- Progging dissipation
  - High loses upper level support (major short wave ridge outruns surface feature).
  - High evolves through its life cycle.
    - Highs typically move southeast and air near center warms (modification and stretching of cP airmass).
    - Frontolysis occurs in advance of high as modified airmass blends with air ahead of front.

Progging surface synoptic features

- High continues southeastward movement and is eventually absorbed by subtropical ridge.

Progging surface synoptic features

- Progging intensity changes
  - Surface pressures fall in areas of divergence/rise in areas of convergence, unless offset by low level temperature advection.
  - Isallobaric indicators for lows
    - Reflect history of system, give clues of future changes (trends can’t always be accurately extrapolated).

Progging surface synoptic features

- 3 hr APP groups are good indication of short term changes (rapid cyclogenesis, for example).

Progging surface synoptic features

- Utilize 24 hr pressure change chart to eliminate diurnal influences.
- If low positioned in isallobaric rise area, low is filling.
- If in isallobaric fall area, low is deepening.

Progging surface synoptic features

- Isallobaric indicators for highs
  - If high is positioned in isallobaric fall area, high is weakening.
  - If in isallobaric rise area, high is building.

Progging surface synoptic features

– Frontogenesis occurs when:

- Air-mass contrast or low level thermal contrast is increasing.
- Front approaches a deep pressure trough (such as Lee-side).
- Angle between thickness lines and axis of dilatation (AOD) less than 45˚.

Progging surface synoptic features

- Divergence is present over the frontal boundary.
- Decresed surface friction.

Progging surface synoptic features

– Frontolysis occurs when:

- Airmass contrast or low level thermal contrast is decreasing.
- Angle between thickness lines and AOD is greater than 45˚.
- Convergence is present over the frontal boundary.
- Increased surface friction caused by terrain.

Progging surface synoptic features

- Steering rules for surface features
  - Extrapolation and continuity
    - These techniques similar to upper-air methods.
    - Trace several 3 hr positions on chart to follow movement.
    - Straight line extrapolation not much use beyond 24 hrs.

Progging surface synoptic features

- Consider terrain.
  - Systems tend to move faster over water.
  - Slow down and become disorganized passing over mountains, reorganizing on leeside.

Progging surface synoptic features

– Steering using upper flow

- Works best when pattern not changing or changing slowly.
- If changing, anticipate and adjust surface forecast for new pattern.
- Do not steer surface using closed flow aloft. Find first level with open flow.

Progging surface synoptic features

– General steering rules for lows

- Will move with forecast long-wave pattern.
- Tend to follow a track similar to previous systems until pattern changes.
- Tend to move toward area of strongest WAA.
- Will move rapidly if low-level WAA is strong and upper-flow is high zonal (low will likely reflect as stable wave).

Progging surface synoptic features

- Stable waves will move along edge of cold air mass, parallel to thickness lines. Ensure no upper support available to develop system.
  - Lows possessing a circular isobaric pattern tend to track toward pressure fall center.
  - Lows possessing elongated isobars will track midway between frontal trough axis and pressure fall center.

Progging surface synoptic features

- Unstable waves tend to move in direction of tightest contour or thermal gradient.
  - If surface isobaric gradient is tighter than thickness gradient, move low parallel to warm sector isobars.
  - If thickness gradient is tighter, move parallel to thickness lines.
  - If both are equal, move midway between the two.

Progging surface synoptic features

- Unstable waves are steered by current at level to which the closed low does not exist (first open flow aloft).
  - Deepening lows will tend to deflect approx. 15˚ to left of steering flow, moving toward lower heights, into areas of upper-level divergence.
  - Filling lows will deflect to 15˚ right of steering flow, toward higher heights, into areas of upper-level convergence.

Progging surface synoptic features

- Lows with warm fronts extending SE and cold front extending W or NW will move SE parallel to thickness lines (in direction of PFJ).

Progging surface synoptic features

- SE moving lows deepen and slow upon recurving to NE.
  - As intensification continues, low will recurve in a more northerly direction.
  - Ideally this rule works best if well defined thickness ridge exists in 1000/500 thickness ribbon or thermal ridge is present at 850 mb.

Progging surface synoptic features

- Mature/Occluded lows will move parallel to isobars ahead of warm front. The 850 mb thermal ridge will usually coincide.
  - Occluded lows, the axis of which are not vertical (still possessing baroclinicity), are steered partly in the direction of the warm air advection and parallel to the strongest winds around the upper low.
  - As occluded lows become more mature, they tend to deflect at greater angles to the left of the jet/steering flow.

Progging surface synoptic features

- Decaying waves (barotropic lows) with nearly vertical axis move with upper low, in direction of height fall center, parallel to strongest winds around low (may not work in western U.S. mountains).
- Lows tend to intensify and slow while passing over Great Lakes in fall and winter due diabatics (heat/moisture source).

Progging surface synoptic features

- Baroclinic lows tend to move at 70% of 700 mb or 50% of 500-mb winds. If either strongly violates continuity, don’t use.

Progging surface synoptic features

- Steering rules for highs
  - Polar outbreak
    - Cold barotropic highs are stationary in source region.
      - » An organized jet (normally from NW) slices across polar airmass.
      - » A portion of airmass breaks off and moves southward as polar outbreak high (baroclinic).

Progging surface synoptic features

- Baroclinic highs will generally move equatorward (SE) even when upper flow is westerly.
  - » Move toward strongest CAA.
  - » Move toward max pressure rises.
  - » Estimate initial movement based on 70% of 700 mb or 50% of 500-mb wind speed, using first open flow aloft (remember, don’t use on an established high if strongly violates continuity).

Progging surface synoptic features

- Highs will strengthen and slow down over the Great Lakes in spring and summer due diabatics (colder surface).

- Once a baroclinic high begins changing to a warm high, it's movement will slow, it will be absorbed by subtropical ridge.

Progging surface synoptic features

- Semi-permanent warm core highs
  - Seasonal movement
    - » Poleward in summer.
    - » Equatorward in winter.
  - Any surface movement associated with movement of upper high.
  - Upper highs move toward height rises or WAA.

Progging surface synoptic features

- Blocking ridges/highs - Well developed upper systems that may reflect as high at surface.
  - Surface systems will not move through block; instead move north, south, or become stationary.
  - Height rise centers tracking toward NW indicate building block.

Progging surface synoptic features

– Steering rules for fronts

- Fronts will move in direction of second standard level winds (if not available use 850-mb flow).
- Cold fronts will move at 85% of second standard level winds behind front.
- Warm fronts will move at 70% of second standard level winds ahead of warm front.
- **IR:**

Progging surface synoptic features

- Control line extrapolation
  - Select control points on front at different time intervals.
  - Connect points.
  - Extend lines forward in time.
  - Use most appropriate for particular system:
    - » Constant movement.
    - » Constant rate of change.
    - » Constant percentage change.

Progging surface synoptic features

Frontal cloud/precipitation relationships.

- Slow moving cold fronts (active cold fronts, speed 10-15 kts)

Frontal cloud/precipitation relationships.

- Slow moving cold fronts are considered active because widespread (synoptic scale) clouds and precipitation occur at and behind the front due to actual frontal lifting.
  - Average slope is approximately 1:100 miles.
  - Parallel flow exists at 700 mb.

Frontal cloud/precipitation relationships.

- Associated cloud types (dependent on stability of warm air mass).
  - When warm air mass is stable, a broad zone of altostratus and nimbostratus clouds accompany the front and extend several hundred miles behind.

Frontal cloud/precipitation relationships.

- If warm air is unstable (or conditionally unstable), thunderstorms and cumulonimbus clouds may develop within the cloud bank and may stretch some 50 miles behind the surface front.
  - These CB's form within the warm air mass.
  - In the cold air there may be some stratus or nimbostratus clouds formed by the evaporation of falling rain; though, most of the time there are relatively few clouds outside of rain areas. (This is due to the descending motion of the cold air which sometimes produces a subsidence inversion some distance behind the front).

Frontal cloud/precipitation relationships.

- Weather and type of precipitation observed is also dependent upon the stability (and perhaps more importantly cloud type) and moisture conditions of the air masses.
  - Visibility is poor in precipitation and may remain so for many hours after FROPA as long as precipitation persists.
  - When cold air behind the front is moist and stable, a deck of stratus/fog may persist for hours after FROPA.

Frontal cloud/precipitation relationships:

- Fast moving cold fronts (inactive cold fronts, speed 25-30 knots)

Frontal cloud/precipitation relationships

- Fast moving cold fronts are considered inactive because lifting occurs at and ahead of the front. Lifting is caused by descending air ahead of the front and only in part by the frontal surface (causing low level convergence with the warm air ahead of the cold front).
  - Average slope is approximately 1:40-1:80 miles.

Frontal cloud/precipitation relationships.

- Perpendicular (within 45° of normal) flow exists at 700 mb.

Frontal cloud/precipitation relationships.

– Type of clouds and weather (dependent on stability of warm air mass).

- When the warm air mass is stable, an overcast layer of altostratus clouds and rain may extend over a large area ahead of the front. If warm air is very dry, little or no cloudiness is associated with the front.

Frontal cloud/precipitation relationships.

- If the warm air is moist and unstable, a line of thunderstorms frequently develops along and just ahead of the front. Stratus, nimbostratus, and altostratus may extend as much as 150 miles ahead of the front in advance of the cumulonimbus.
  - Sometimes a parallel line of strong convective activity is projected 50 to 200 miles ahead of the front (squall line).
  - If the squall line is far enough in advance of the front, strong pressure rises, wind shifts, and temperature falls (associated with evaporation of falling precipitation) will likely occur with passage. However, the winds will become southerly, pressures will level off, and the temps will become consistent with the warm air mass prior to FROPA.

Frontal cloud/precipitation relationships.

  - Dew point and wind direction are good indicators of passage of the actual cold front. Dew points drop rapidly after FROPA. Winds veer and are strong, gusty, and turbulent for a considerable time after passage.

- Generally, unless the cold air is unstable and descending currents weak, few clouds will exist in the cold air behind the front.

Frontal cloud/precipitation relationships.

- Warm fronts (average speed 10-20 knots)
  - Average slope between 1:100 and 1:300 miles.
  - Warm fronts have characteristically shallow slopes caused by the effect of friction which retards frontal movement at the surface.

Frontal cloud/precipitation relationships.

- Characteristic of a typical warm front is the sequence of cloud formations which occur in the following order as front approaches: cirrus, cirrostratus, altostratus, nimbostratus, and stratus.
  - Cirrus clouds may precede the warm front 700 to 1000 miles or more.
  - Cirrus is followed by cirrostratus found at about 600 miles in advance of the warm front.
  - Cirrostratus is followed by altostratus found at about 500 miles in advance of the warm front.

Frontal cloud/precipitation relationships.

- The amount and type of clouds and precipitation vary with the characteristics of the air masses involved and depending on whether the front is active or inactive.
  - An active warm front exists when the perpendicular (to the front) wind component increases with height. This produces strong overrunning and pronounced prefrontal clouds and precipitation.
  - An inactive warm front exists when the perpendicular wind component decreases with height. Inactive warm fronts are characterized by broken cirrus and altocumulus.

Frontal cloud/precipitation relationships.

- When the overrunning warm air is moist and stable, nimbostratus clouds with continuous (or intermittent) light to moderate precipitation are found approximately 300 miles ahead of the front. The type of precipitation is dependent on temperature of the cold air mass and height of the freezing level.

- Ceilings lower rapidly as additional clouds form in the cold air under the frontal surface (caused by evaporation of falling rain).

  - If the cold air is stable, these clouds will be stratiform.

  - If cold air is unstable, they will be stratocumulus.

Frontal cloud/precipitation relationships.

- When the overrunning air is moist and unstable, cumulonimbus clouds are frequently imbedded in the nimbostratus and altostratus. In such cases, thunderstorms and showers occur along with continuous precipitation types.
- When overrunning air is dry, it must ascend to higher altitudes before condensation occurs. In such cases, only high and middle clouds are observed.

– Clearing usually occurs after passage. Stratocumulus may be present in the warm air. Cumulonimbus may be present in the warm air in summer.

Frontal cloud/precipitation relationships.

- Occluded fronts
  - A composite of two fronts. Formed when a cold front overtakes a warm front resulting in one of the two fronts being displaced upward. As a result, warm air between the cold and warm front is shut off (lifted).
  - Since occlusions are a combination of cold and warm fronts, the resulting weather is that of the cold front’s narrow band of violent weather and the warm front’s widespread area of cloudiness and precipitation.

Frontal cloud/precipitation relationships.

- There are two types. Warm occlusions and cold occlusions.
  - Cold occlusions occur when the cold air in advance of the warm front is warmer than the cold air behind the cold front. Since the air associated with the cold front is more dense, it undercuts the cool air ahead of the warm front forcing the warm front aloft.
    - In the cold occlusion, the displaced upper warm front follows the surface occluded front by 20 to 50 miles.
    - In the initial stages of development, the cloud and weather sequence ahead of the occlusion is similar to that with warm fronts; however, at the surface it is similar to that of cold fronts.

Frontal cloud/precipitation relationships.

- Most precipitation occurs just ahead of the occlusion.

- The most violent weather occurs at the apex (or triple point) of the occlusion.

- Clearing behind the occlusion is usually rapid, especially if in the advanced stages. In the initial stages, clearing may not occur until passage of the upper warm front.

Frontal cloud/precipitation relationships.

- Warm occlusions form when the air in advance of the warm front is colder than the air behind the cold front. When the air of the cold front overtakes the warm front, it moves up over the colder air to form an upper cold front.
  - In a warm occlusion, the upper cold front precedes the surface occluded front by as much as 200 miles.
  - The sequence of clouds ahead of the occlusion is similar to that ahead of a warm front.
  - If either the warm or cool air that is lifted is moist and unstable, showers and sometimes thunderstorms may develop. When they do they will occur just ahead of the upper cold front (it is not uncommon to see the upper cold front represented on the surface chart).

Frontal cloud/precipitation relationships.

- The intensity of the weather associated with the upper front decreases with distance from the apex (triple point).
- Weather conditions change rapidly in occlusions and are usually most severe in the initial stages.
- As the warm air is lifted to higher levels, the weather activity diminishes.

Frontal cloud/precipitation relationships.

- Quasi-stationary fronts (a.k.a. stationary fronts)
  - Quasi-stationary fronts defined
    - A quasi-stationary front is a front along which one air mass is not appreciably replacing another air mass.
    - The term stationary is actually a misnomer since it would be very unusual for two air masses of different properties to be side by side without some movement.
    - Actually the front is most likely made up of small waves undulating back and forth; hence the term quasi-stationary.

Frontal cloud/precipitation relationships.

- A front moving less than 5 knots is usually classified as stationary.

Frontal cloud/precipitation relationships.

- Characteristics
  - When a front is stationary, the cold air mass does not move either toward or away from the front.
  - In terms of wind direction, this means the wind above the friction layer blows neither toward nor away from the front, but parallel to it.
  - Wind shifts across the front are usually near 180˚.
  - It follows that the isobars are nearly parallel to a stationary front making recognition easy on a surface chart.

Frontal cloud/precipitation relationships.

- There is frictional inflow of warm air toward a stationary front causing a slow upglide of air on the frontal surface. As the air is lifted to saturation, clouds form above the front.

- The width of the band of precipitation and low ceilings vary from 50 to about 200 miles depending upon frontal slope and the temperatures of the air masses.

Frontal cloud/precipitation relationships.

- Stable stationary front
  - If the warm air in a stationary front is stable and the slope shallow, the clouds are stratiform. Drizzle may fall, and as the air is lifted beyond the freezing level, icing conditions develop and light rain or snow may fall.
  - If the slope is steep and significant warm air is advected up the frontal slope, stratiform clouds with embedded showers result. Slight undulation or movement of the front toward the warm air mass intensifies the activity.

Frontal cloud/precipitation relationships.

- Unstable stationary front
  - If the warm air is conditionally unstable, the slope is shallow, and sufficient lifting occurs, the clouds are then cumuliform or stratiform with embedded towering cumulus.
    - » If the energy release is great (warm, moist, unstable air), thunderstorms result.
    - » The shallow slope results in a very broad and extensive area of showers, fog, and reduced visibility.
  - If the slope is steep and sufficient warm air is advected up the slope or the front moves slowly toward the warm air mass, violent weather can result. Heavy rain, severe thunderstorms, strong winds, and tornadoes can occur.

Progging the surface weather depiction

- Clouds
  - Cirrus/Cirrostratus (high etage)
    - While these clouds can be very extensive in the horizontal, they typically possess a relatively shallow vertical extent.
    - Common vertical extents average between 1,000 to 2,000 ft.
    - Either Ci or Cs may be present alone or together.
    - Layering is not uncommon.

Progging the surface weather depiction

– Altocumulus/Altostratus (mid etage)

- These clouds can also be very extensive in the horizontal but aren't very extensive in the vertical.
- Common vertical extents range from 1,000 to 2,000 ft for As and from 1,000 to 5,000 ft for Ac.
- Ac and As may exist alone or together.
- Layering is very common.

Progging the surface weather depiction

– Nimbostratus (mid to low etage)

- This is a very extensive cloud type both in the horizontal and the vertical.
- Vertical extent averages from 10,000 to 20,000 ft.
- This cloud typically lowers over time due to falling precipitation.

Progging the surface weather depiction

- Stratus/Stratocumulus/Cumulus/Cumulonimbus (low etage)
  - For cumuliform clouds, the stability of a region will dictate both the horizontal and vertical extent.
  - Stratus is a stable cloud form that ranges from 1,000 to 4,000 ft in vertical extent. Stratus is at times very extensive horizontally.
  - Stratocumulus exists where the atmosphere is stable and is typically wider horizontally than it is deep vertically. Average vertical extent is 1,000 to 4,000 ft.

Progging the surface weather depiction

- Cumulus and Cumulonimbus exist when the atmosphere is unstable. The degree of instability dictates the extent of vertical development. The vertical extent may range from several thousand feet for cumulus to 50,000 feet or more for cumulonimbus.

Progging the surface weather depiction

- Ceilings
  - Progs will be a basic nephanalysis based on the following criteria:
    - Enclose ceilings less than 1,000 ft using a solid red line.
    - Ceilings greater than or equal to 1,000 ft but less than 3,000 ft are enclosed in a scalloped blue line.
    - Greater than or equal to 3,000 ft but less than 10,000 ft are depicted with a scalloped purple line.

Progging the surface weather depiction

- Ceilings greater than or equal to 10,000 ft are depicted in scalloped brown.
- Label ceilings with the following information:
  - Cloud amount in eighths (octas).
  - Follow cloud amount with two letter cloud type (Sc, Cu, As, etc.). If two cloud types exist in conjunction or are layered, list both and separate with a "/".
  - Follow cloud type with cloud bases and tops in three digits (10,000's, 1,000's, 100's). Bases go under tops and are separated by a line (for solid cloud decks). Use the abbreviation "LYRD" instead of the line when multiple decks aren't separated by an appreciable distance.

Progging the surface weather depiction

- Consistency is the key! Don’t label a blue scalloped area (low etage) as Ac or As (mid etage clouds).

Progging the surface weather depiction

- Precipitation areas
  - Clouds and related precipitation types
    - Cumulus (Cu) of strong vertical extent can produce showery precipitation.
    - Cumulonimbus (Cb) is more often than not accompanied with thunder and like Cu produces showery precipitation.
    - Stratocumulus (Sc) which is not the result of a stablizing situation (Sc from Cu), can produce light precipitation of a continuous or intermittent character.

Progging the surface weather depiction

- Stratus (St). Any precipitation produced by this cloud type is in the form of drizzle or snow grains. The exception would be if the Stratus were underneath Nimbostratus.

- Altostratus (As) may become sufficiently dense and become Nimbostratus (Ns). Ns will very often extend into the low etage and is associated with precipitation of a continuous character.

Progging the surface weather depiction

- Depict precipitation areas as follows:
  - Outline areas of continuous precipitation with a solid green line. Depict type and intensity with appropriate symbol.
  - Outline areas of showery precipitation with an alternating dash/dot pattern in green. Depict type and intensity with appropriate symbol.
  - When two types of precipitation are forecast for the same area, list the predominant type first and separate by a solidus.

Progging the surface weather depiction

- Separate areas of liquid and frozen precipitation by a solid green line.

- Depict thunderstorm areas with an alternating dash/dot pattern in red. Over the appropriate thunderstorm symbol (depicted red), indicate max top(s) using three digits in black.

- Finally, be consistent. Don't indicate precipitation under cloud types that won't produce precipitation (i.e., rainshowers under a Cs canopy). Likewise, don't indicate rainshowers under strictly stable cloud types (i.e., rainshowers under Ns alone).

- APPLICATION: Throughout the entire lesson.
- EVALUATION: Progress Check and Written Test